Using IMERG to Define Upscale Growth of Tropical Oceanic Mesoscale Convective Systems

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1. Background and Science Questions

Mesoscale Convective Systems (MCSs) account for a large percentage of tropical precipitation (Rickenbach and Rutledge 1998; Liu 2011) and have distinct impacts on atmospheric heat, moisture, radiation, and momentum (Houze 2015).

Upscale growth is the process whereby small convective systems grow into larger MCSs. While this process has been heavily studied for MCSs over mid-latitude land, it is relatively poorly understood for MCSs over tropical oceans, partially because of the difficulty in observing and defining MCSs. Although key links between precipitation rate and the organization of MCSs over tropical oceans have been made with moisture, shear, and tropical waves, there is still little understanding of the exact processes driving upscale growth over tropical oceans.

Science Questions

1. How can we represent upscale growth of large samples of tropical oceanic MCSs with a pseudo-observational global precipitation dataset?
2. Where, when, and how does upscale growth of tropical oceanic MCSs occur?

2. Data

The Integrated Multi-satellitE Retrievals for GPM (IMERG; Huffman et al. 2019) is a global precipitation dataset that integrates and morphs data from microwave and infrared satellite imagery. It has spatial resolution of 0.1˚ and temporal resolution of 30 mins. This makes it ideal for identifying a global set of precipitation features (PFs) that are continuous in time, with which we can estimate upscale growth.

3. What is Upscale Growth?

A typical definition of upscale growth is the increase in area of a contiguous region of precipitation. Fig 1 is an example of such an ideal case.

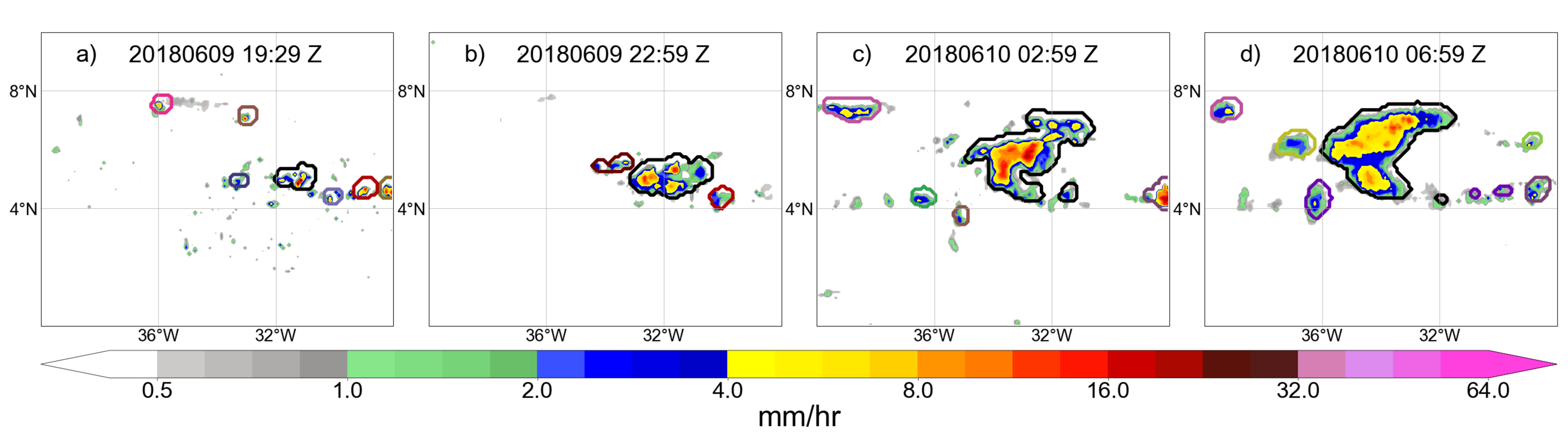


Fig 1: An isolated convective system (outlined by the black contour) that grows upscale.

However, over tropical oceans in the ITCZ most convective systems are more complex, undergoing multiple mergers and splits during their lifetime (Fig 2).

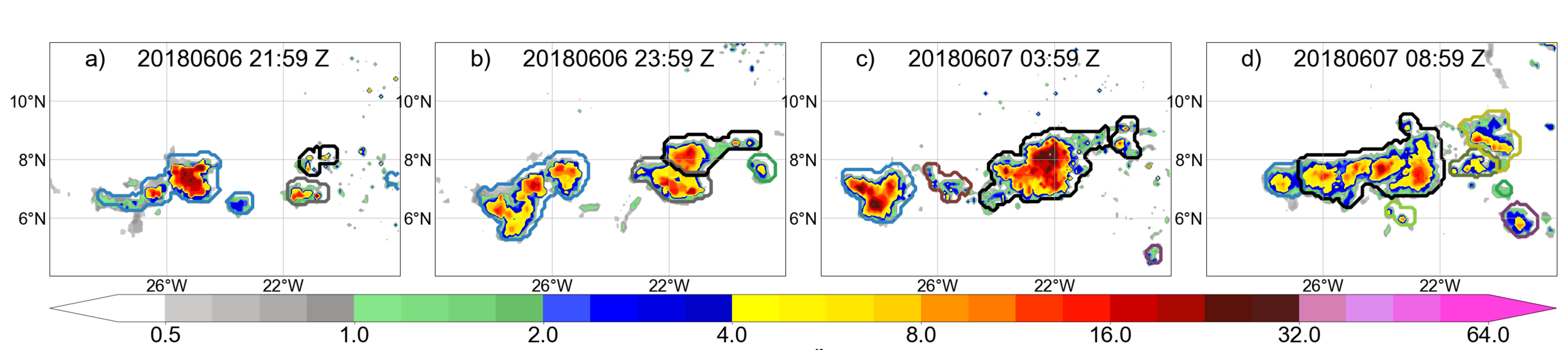


Fig 2: A common convective system over tropical oceans in the ITCZ undergoing multiple mergers.

Using the typical definition of a PF as a contiguous area of precipitation, there will be sudden rises/falls in area due to mergers/splits. Further mergers and splits make it difficult to track PFs. How then can we define MCSs and their upscale growth?

4. Defining and Tracking MCSs

In Fig 3 the contiguous area of precipitation would subjectively not be defined as an MCS. Rather, it may be divided into 8-12 systems. How can we do this in an objective and reproducible manner?

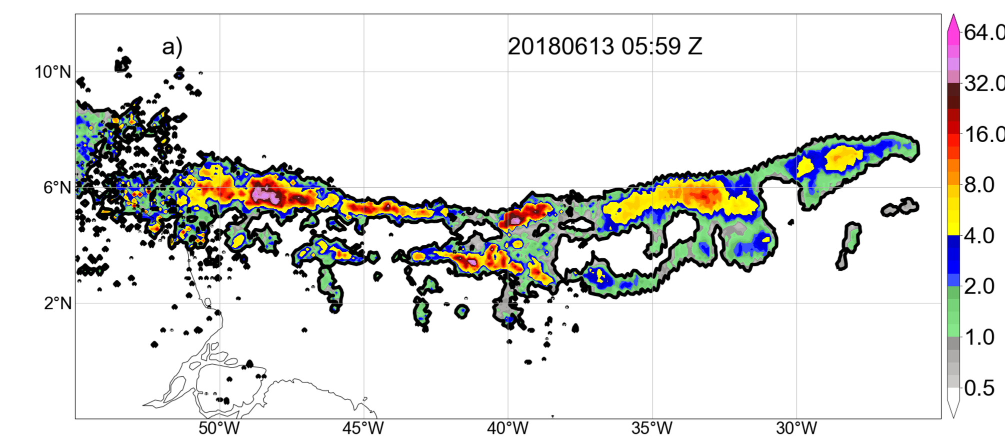


Fig 3: How many systems would you define in this large contiguous area? (Subjective)

We use a tracking algorithm from Skok (2013). It defines system boundaries not using contiguous area but based on cascading thresholds of rain rates that break the contiguous area in to multiple systems (Fig 4). Current work is examining the optimal set of tracking parameters to deal with mergers and splits.

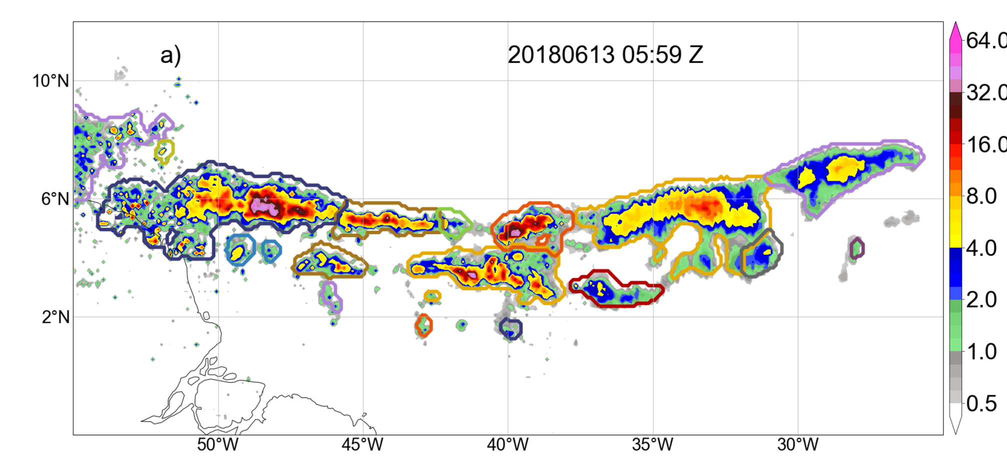


Fig 4: Objectively defined boundaries by Skok algorithm

5. Representing Upscale Growth

Using aircraft data from the NASA Convective Processes Experiment (CPEX), we found that IMERG created spurious areas of light precipitation associated with MCSs. This is a result of time morphing (interpolation) between passive microwave (PMW) overpasses. Below 0.5 mm/hr time-morphed areas of IMERG have a higher probability of light precipitation than areas with a PMW overpass. This has implications for defining upscale growth since typical definitions based on PF area will be affected by these spurious precipitation areas.

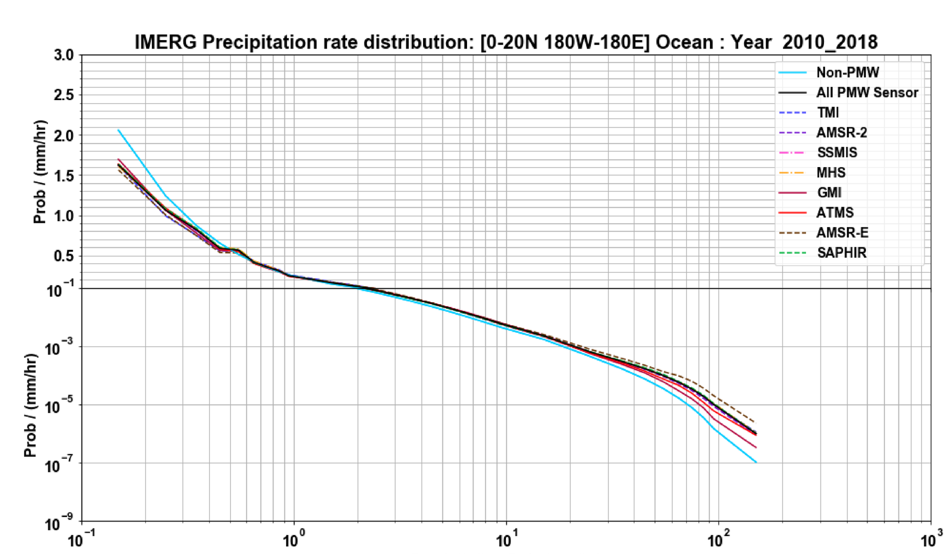


Figure 5: Precipitation rate distribution PMW area vs interpolated area

We find that volumetric rain rate (VRR) is less sensitive to time-morphing than the PF area. Thus, we define upscale growth using both the area and volumetric rain rate of a PF. For upscale growth we specify that there must be:

- Doubling of both area and VRR
- Max duration and area of 6 hours and 1000 km²
- Have a rain rate of 10 mm/hr
- >90% of area and VRR change cannot occur in 30 mins

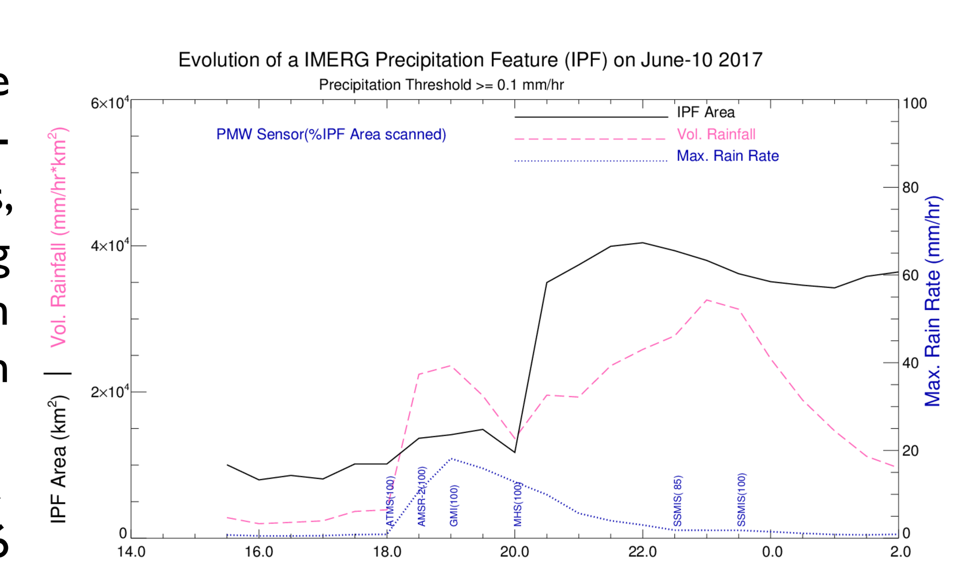


Fig 6: Time-series of volumetric rain rate, area, and max rain rate for an MCS investigated on June 10th 2017 during the CPEX field campaign.

6. Upscale Growth of Precipitation Features

- Upscale growth location is primarily limited to the ITCZ with few elsewhere.
- There is little variability within the ITCZ.

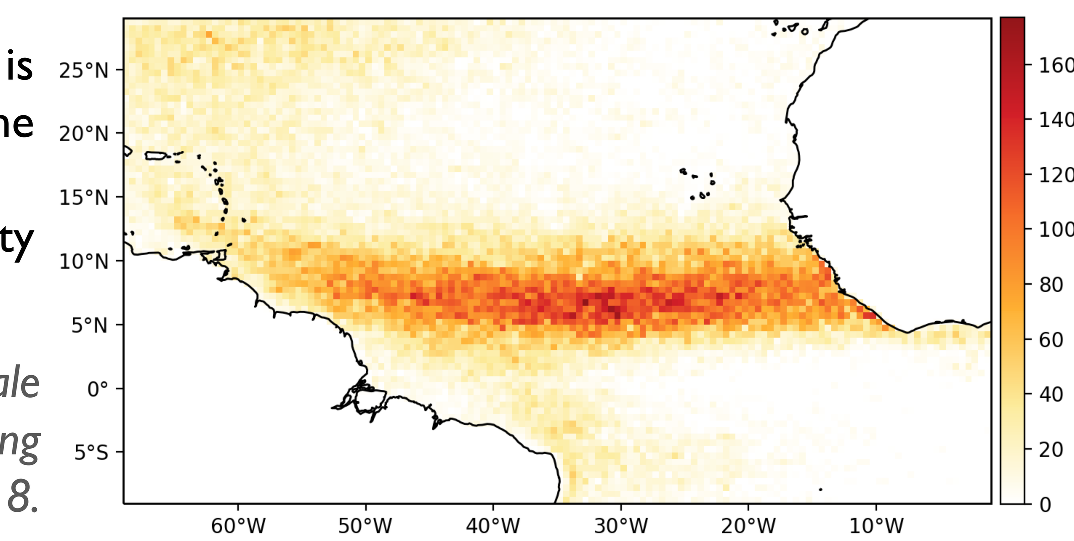
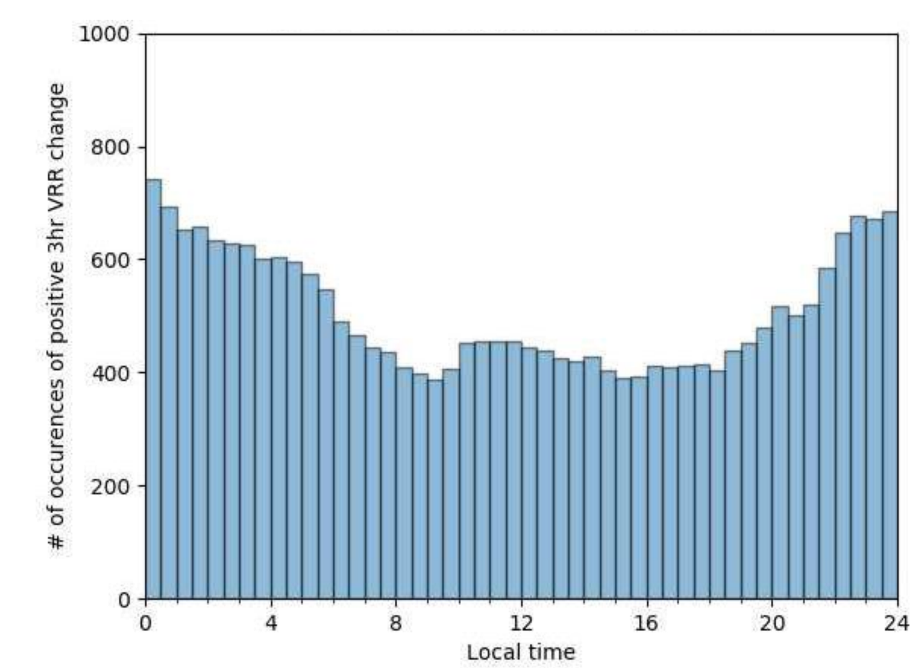


Figure 7: Occurrences of upscale growth by PF centroid during June-September 2014-2018.



- Upscale growth over the tropical Atlantic exhibits a diurnal cycle with a nocturnal maximum.
- This is consistent with past work showing an early morning peak in PFs volumetric rain rate.

Figure 8: Occurrences of upscale growth for domain as in Figure 7 by local time of day for June-September 2018.

- The number of PFs exhibiting growth varies substantially by day with notable periods of increased activity.
- This indicates various different controlling factors such as easterly and equatorial waves.

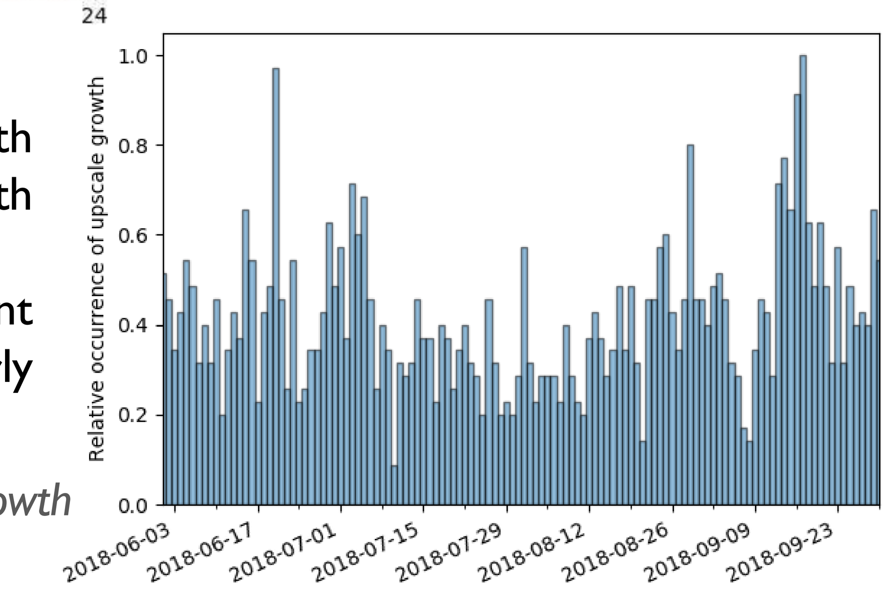


Figure 9: Relative occurrence of upscale growth per day between 20-30W, 0-20N.

7. Summary and Future work

We may now expand this dataset to:

- 20 years (2000-2019)
- Incorporate other ocean basins (East , Central, West Pacific, and Indian Ocean).
- Examine other seasons.

This will allow us to investigate when and where upscale growth occurs on a global scale with a statistically large sample.

The remaining, and arguably most important question, is how upscale growth occurs. This can be tested using power spectra, and by correlating and compositing IPFs against environmental variables such as temperature, moisture, and winds.

8. Acknowledgements & References

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References

1. Houze Jr, R.A., Rasmussen, K. L., Zuluaga, M. D., & Brodzik, S. R. (2015). The variable nature of convection in the tropics and subtropics: A legacy of 16 years of the Tropical Rainfall Measuring Mission satellite. *Reviews of Geophysics*, *53*(3), 994-1021.
2. Huffman, G. J., D.T. Bolvin, D. Braithwaite, K. Hsu, R. Joyce, C. Kidd, E. J. Nelkin, S. Sorooshian, J. Tan, P. Xie, 2018: *Algorithm Theoretical Basis Document (ATBD) Version 5.2* for the NASA Global Precipitation Measurement (GPM) Integrated Multi-satellite Retrievals for GPM (IMERG).
3. Liu, C., 2011: Rainfall Contributions from Precipitation Systems with Different Sizes, Convective Intensities, and Durations over the Tropics and Subtropics. *J. Hydrometeor., 12, 394–4120.*
4. Rickenbach, T.M. and S.A. Rutledge, 1998: Convection in TOGA COARE: Horizontal Scale, Morphology, and Rainfall Production. *J. Atmos. Sci., 55, 2715–2729.*
5. Skok, G., J. Bacmeister, and J. Tribbia, 2013: Analysis of Tropical Cyclone Precipitation Using an Object-Based Algorithm. *J. Climate, 26, 2563–2579*